IV. REMARKS

Claims 1-17 stand rejected, as final, under 35 USC §103(a).

In the present Office Action, claims 1 and 2 stand rejected as Final under 35 USC 103(a) as being unpatentable over U.S. Patent 6,767,530 ("Kobayashi"), or in the alternative in view of U.S. Patent 2,556,835 ("Barr") and any one of U.S. 2002/183402 ("Okado et al."), U.S. Patent 6,312660 ("Okado et al.") and U.S. Patent 6,749,828 ("Fukunaga").

This rejection is respectfully traversed in part.

The Examiner correctly notes that Kobayashi teaches a process for steam reforming a hydrocarbon to produce a hydrogen containing synthesis gas, followed by heat recovery step, and an optional water gas shift reaction to increase the hydrogen content of the synthesis gas. Kobayashi also teaches a second heat recovery step and water condensation step, followed by pressure swing adsorption to separate a hydrogen stream from CO_2 and other gases. These process steps are each performed serially. Kobayashi then reverses the cycle, taking the desorbed gas species, i.e. the tail gas of the pressure swing absorption gas separation step to a heat transfer bed to preheat the CO_2. The pre-heated CO_2 is further heated in a furnace. Thereafter, an oxidant is added, and passed to a burner furnace for combustion. The heated combustion stream is then passed from the furnace zone to the regenerative reactor bed to reheat that bed for the next cycle's reforming (see Col. 5, line 2 through Col. 6, line 11). These processes are all done serially.

Applicants' invention differs from Kobayashi's in at least two substantial ways:

- the actual reforming step and the first step of heat recovery are done at a space velocity of at least 1000 hr^{-1}, and

- the "reverse cycle" of applicants' process uses only the regenerative zone and reforming zone.

As noted by Examiner, Kobayashi does not teach the process space velocities of the present invention. The Examiner, however, also notes that Kobayashi teaches controlling the pressure of the process and that a skilled artisan would optimize the pressure of the process as a result effective variable. This aspect of the Examiner's rejection is respectfully traversed. Controlling the pressure of the process is not a distinguishing characteristic of the applicants' invention relied on herein, whereas controlling the space velocity during the reforming and heat recovery process steps is.

Moreover, controlling the process pressure is not analogous to or suggestive of controlling the space velocity of the reforming and heat recovery process. Nothing taught in Kobayashi would lead the skilled practitioner to the claimed range of space velocity of the present application. Applicants have discovered that operating two steps of their process, i.e. the reforming step and the heat recovery step, at a space velocity above about 1000^{-1} hr, results in substantial efficiency gains. Kobayashi teaches "improved overall energy efficiency" by combining cyclic regenerative reforming with a pressure swing absorption process (see col. 2, line 7 et seq.). The skilled reader of Kobayashi would, therefore, be led to increase efficiency by improving the integration of cyclic reforming and pressure swing adsorption. Nothing contained in Kobayashi would lead the skilled practitioner to consider varying space velocity to increase efficiency, nevertheless the very high space velocities of the present invention.

Additionally, Kobayashi teaches the use of each zone or region in both the forward and reverse cycle (see Figures 1 and 2), contrasted with applicants' shift and separation means performed only in the "forward" or syngas/hydrogen

production cycle. In so doing, applicants substantially reduce reactor volumes that are subject to reverse-cycle flow, and do not expose their shift reaction catalyst to the reverse cycle gases (including highly carburizing CO concentrations) required by Kobayashi. Additionally, Kobayashi's lack of concern for reactor volumes evidence by all reactions being serial and required for each cycle, teaches away from a consideration of space velocity as a means for improving efficiency. For at least these reasons, applicants submit that their claims 1 and 2 are not rendered obvious by Kobayashi.

The Examiner's rejection of claims 1 and 2 is alternatively based on Kobayashi in view of U.S. Patent 2,556,835 ("Barr") and any one of U.S. Patent applications 2002/0183902 ("Okado"), U.S. Patent 6,312,660 ("Yagi") U.S. Patent 6,749,828 ("Fukunaga"). This rejection is respectfully traversed.

Barr illustrates how long the industry has pursued technology to efficiently produce hydrogen. This patent, assigned to a predecessor of the assignee herein, teaches regenerative reforming at elevated pressures, preferably 5 to 50 atmospheres. Note that Barr's reforming space velocity is roughly $75hr^{-1}$.

However, the skilled practitioner considering the combined teaching of Kobayashi in view of Barr would be instructed to increase the reforming pressure of the Kobayashi process. This neither teaches or suggests operating the reforming and heat recovery steps of the process at the very high space velocities taught in the present invention.

The Examiner additionally bases his rejection on Kobayashi in view of Barr and any one of Okado, Yagi and Fukunaga. This rejection is respectfully traversed. The Examiner correctly notes that Okado, Yagi and Fukunaga teach reforming at high space velocity. Each of these references, however, teach reforming in a fixed bed steady-state, isothermal reactor. Each of these references

teach improved reforming by means of then novel reforming catalysts. Applicant's submit that a skilled practitioner would not apply the process conditions from either Fukunaga, Yagi, or Okado to reverse-cycle regenerative bed reforming, such as exemplified by Kobayashi.

At least three factors must be satisfied to achieve a target space velocity in a catalytic reactor:

(1) the catalyst must have and maintain sufficient catalytic activity to react feed at a rate corresponding to the target space velocity;

(2) the reacting system must provide sufficient mass transfer rates to get feed to the catalyst(s) and products away from the catalyst at a rate corresponding with the targeted space velocity;

(3) if the reaction is substantially exothermic or endothermic, there must be means to provide or remove the heat of the reactions, at a rate corresponding to the target space velocity.

Fukunaga teaches auto thermal and CO_2 reforming under <u>steady state</u> conditions, not reverse flow. Fukunaga's reactions are carried out at a fixed temperature of 780°, evidently heated continuously by a furnace system (not regenerative bed(s)). Yagi teaches steam or CO_2 reforming at fixed isothermal steady state conditions (not cycled), at about 850° (not regenerative bed(s)). Okado teaches steady state reforming at a fixed temperature of 840°C also, not regenerative bed(s)).

These three all teach steady-state, non-cyclic, reactions.

The skilled practitioner would not be expected to adopt the high space velocity rates of these steady-state processes because of the substantial impact on

the other process conditions and reactor(s) design and configuration, most notably the ability to supply or withdraw heat, and maintain sufficient catalyst activity at those rates and not be damaged during reverse flow condition (including exposure to oxygen). The skilled artisan would, ab initio, recognize that the heat supply and transfer characteristics of a reverse flow regenerative bed system are so different from a steady-state reactor that it would be imprudent to adopt their space velocity. The skilled practitioner recognizes that you cannot select one process condition from those steady-state reactions and apply it to a reverse flow reactor system. At minimum, the steady-state reactors of these references are not heat rate limited; these are isothermal reforming and therefore gas to solids heat transfer properties are not a critical parameter as in reverse cycle, regenerative bed reforming systems. For at least these reasons, the skilled practitioner of cyclic, reverse flow regeneration and reforming would not adopt the high space velocities of Fukunaga, Okado or Yagi.

Claims 3-8 stand rejected under 35 USC 103(a) as unpatentable over Kobayashi in view of Barr and U.S. Patent 6,299,994 ("Towler"). More particularly, The Examiner notes that while Kobayashi fails to teach the claimed temperature of the flue gas exiting the reformer, Towler teaches a process for producing hydrogen wherein a reformate effluent stream at a temperature below 700°C is passed to a water shift reaction zone operated at a temperature of about 400-450°C. This rejection is respectfully traversed.

As detailed above, Kobayashi neither teaches nor suggests to the skilled practitioner, conducting the reforming and heat recovery steps of the process at the very high space velocities claimed herein. Additionally, while Towler teaches a method for producing hydrogen, as noted by the Examiner, Towler teaches a very different reforming process having a reforming zone temperature that is below about 700° (col. 13, line 47). Towler describes a catalytic autothermal reforming process where the reform feed is first partially oxidized (adding air) and then

adiabatically reformed. The outlet syngas temperature in Towler is the temperature at the exit of the catalytic reforming bed, without heat exchange, and this temperature is controlled by the amount of air added, which dictates the balance between exothermic combustion of the reform feed and subsequent endothermic reforming. Syngas is made at a temperature below 700°C by controlling the amount of oxidant used to partially oxidize the reform feed. In contrast, Applicants' do not partially oxidize their reform feedstock. Applicants' Syngas temperature is not the temperature exiting the reform catalyst, but is the temperature achieved after passing through the "second zone" regenerative heat exchanger. Applicants control their temperature by the design of the zone's heat transfer properties, not by addition or withholding an oxidant to the reform feed.

The Examiner also notes that Towler's stream is passed to a water gas shift catalyst at 400-450°C. This is true, however, Towler adds water to the syngas and cools it to get to 400-450°C. The present invention's reforming conditions heat the reforming zone to a temperature in the range of about 700° to 2000°. Operating the process taught by Kobayashi at the reforming, water gas shift and combustion temperatures taught by Towler would likely result in inoperative reforming or highly inefficient reforming. For at least these reasons, applicants respectfully submit that claims 3-8 are not obvious over Kobayashi in view of Towler.

Claim 9 stands rejected under 35 USC 103(a) as unpatentable over Kobayashi, or alternatively over Kobayashi in view of Barr and US Patent 6,338,239 ("Hirata"). The Examiner noted that while Kobayashi fails to teach the air provided in the regeneration cycle is compressed air, Hirata teaches a turbine and reformer system wherein fuel is combusted with compressed air to produce electricity and heat the reformer.

This rejection is respectfully traversed.

Claim 9 should be deemed allowable over Kobayashi for the reasons set forth in respect of claims 1, from which this claim depends. Similarly, Barr and Hirata are both silent in respect of space velocity. Therefore, claim 9 should not be deemed obvious over Sederquist in view of Barr and Hirata.

Additionally, in respect of the subject matter of claim 9, i.e. the use of compressed air from a gas turbine in the regeneration cycle, Hirata does not teach or suggest the use of compressed air in the type of reforming taught in Kobayashi. Hirata teaches reforming at low pressure to improve equilibrium at low (500°C) reforming temperature. This results in the need to add a compressor to pressurize the reform product for use in the gas turbine. For at least these reasons, the skilled practitioner would not be motivated by Hirata to use compressed air in the regenerative cycle of a reverse flow reactor as claimed herein.

Claims 10-15 and 17 stand rejected under 35 USC 103(a) as unpatentable over Kobayashi in view of Barr and Towler and US 4,240,805 ("Sederquist"). This rejection is respectfully traversed. Applicants submit they have addressed Kobayashi, and Kobayashi in view of Barr and Towler, and have demonstrated, at minimum, that these references singularly or in combination, do not teach or suggest cyclic regenerative bed reforming at a high space velocity, as set forth in claim 10, and claims dependent thereon.

In his rejection, the Examiner notes that although Kobayashi fails to teach two reforming zones, Sederquist teaches a reforming process for producing hydrogen (col. 1) wherein there are two reforming zones wherein the first reforming zone contains packing comprising alumina or magnesium oxide (col. 6) and a steam reforming catalyst (col. 8) and that packing material may be present in both reforming zones (col. 8). The Examiner thereby contends it would have been obvious to one of ordinary skill in the art to provide a first reforming zone

containing packing materials and a steam reforming catalyst and the second reforming zone containing bed-packing materials at a temperature lower than the first reforming zone because Sederquist teaches that both reforming zones may contain only packing material (col. 8) but that reform catalyst may be used to drive the hydrocarbon conversion to completion (col. 8).

Applicants respectfully point out that none of the rejected claims 10-15 or 17 recite a second reforming zone.

In the same rejection, the Examiner asserts that while Kobayashi fails to teach the space velocities of the present invention, Fukunaga, Yagi or Okado teach steam reforming at high space velocity.

As detailed above, these three references all teach steady-state, non-cyclic, reactions.

As detailed above, the skilled practitioner would not be expected to apply the high space velocity rates of these steady-state processes to a reverse flow, cyclic reactor because of the substantial impact on the other process conditions, most notably the ability to supply or withdraw heat, and maintain sufficient catalyst activity at those rates and not be damaged during reverse flow condition (including exposure to oxygen). For at least these reasons, the skilled practitioner of cyclic, reverse flow regenerative bed reforming would not adopt the high space velocities of Fukunaga, Okado or Yagi.

Claim 16 stands rejected under 35 USC 103(a) as unpatentable over Kobayashi in view of Barr and Towler and Sederquist and Horata. More specifically, the Examiner contends that Kobayashi teaches a process for producing hydrogen but fails to teach that the air provided in the regeneration cycle is compressed air, however, Hirata teaches a turbine and reformer system

wherein fuel is combusted with compressed air for the purpose of providing electricity and providing means for raising the temperature of the reformer. The Examiner contends it would have been obvious to one of ordinary skill in the art at the time applicants' invention was made to provide fuel combusted with compressed air in Kobayashi to provide electricity and providing means for raising the temperature of the reformer.

This rejection is respectfully traversed.

Applicants submit that they have above detailed why claim 10 is not obvious over Kobayashi in view of Hirata. Applicants rely upon that reasoning in submitting that claim 16, which is dependent for claim 10, is patentable.

Applicants believe they have addressed each of the Examiner's rejections, setting forth the basis of distinction(s) of their invention over the prior art. If there are any remaining issues, the applicants urge the Examiner to call their undersigned attorney.

Respectfully submitted,

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